Available online at www.sciencedirect.com
SCIENCE DIRECT®
Analytica Chimica Acta 538 (2005) 355–374
ANALYTICA CHIMICA ACTA
www.elsevier.com/locate/aca

Water quality assessment and apportionment of pollution sources of Gomti river (India) using multivariate statistical techniques—a case study

Kunwar P. Singh [a,*], Amrita Malik [a], Sarita Sinha [b]

[a] *Environmental Chemistry Section, Industrial Toxicology Research Centre, Post Box 80, MG Marg, Lucknow 226 001, India*
[b] *National Botanical Research Institute, Rana Pratap Marg, Lucknow 226 001, India*

Received 31 October 2004; received in revised form 30 January 2005; accepted 1 February 2005
Available online 9 March 2005

Abstract

Multivariate statistical techniques, such as cluster analysis (CA), factor analysis (FA), principal component analysis (PCA) and discriminant analysis (DA) were applied to the data set on water quality of the Gomti river (India), generated during three years (1999–2001) monitoring at eight different sites for 34 parameters (9792 observations). This study presents usefulness of multivariate statistical techniques for evaluation and interpretation of large complex water quality data sets and apportionment of pollution sources/factors with a view to get better information about the water quality and design of monitoring network for effective management of water resources. Three significant groups, upper catchments (UC), middle catchments (MC) and lower catchments (LC) of sampling sites were obtained through CA on the basis of similarity between them. FA/PCA applied to the data sets pertaining to three catchments regions of the river resulted in seven, seven and six latent factors, respectively responsible for the data structure, explaining 74.3, 73.6 and 81.4% of the total variance of the respective data sets. These included the trace metals group (leaching from soil and industrial waste disposal sites), organic pollution group (municipal and industrial effluents), nutrients group (agricultural runoff), alkalinity, hardness, EC and solids (soil leaching and runoff process). DA showed the best results for data reduction and pattern recognition during both temporal and spatial analysis. It rendered five parameters (temperature, total alkalinity, Cl, Na and K) affording more than 94% right assignations in temporal analysis, while 10 parameters (river discharge, pH, BOD, Cl, F, PO_4, NH_4–N, NO_3–N, TKN and Zn) to afford 97% right assignations in spatial analysis of three different regions in the basin. Thus, DA allowed reduction in dimensionality of the large data set, delineating a few indicator parameters responsible for large variations in water quality. Further, receptor modeling through multi-linear regression of the absolute principal component scores (APCS-MLR) provided apportionment of various sources/factors in respective regions contributing to the river pollution. It revealed that soil weathering, leaching and runoff; municipal and industrial wastewater; waste disposal sites leaching were among the major sources/factors responsible for river quality deterioration.

Keywords: Gomti river; Water quality management; Cluster analysis; Factor analysis; Principal component analysis; Discriminant analysis; Source apportionment

1. Introduction

The surface water quality is a matter of serious concern today. Rivers due to their role in carrying off the municipal and industrial wastewater and run-off from agricultural land in their vast drainage basins are among the most vulnerable water bodies to pollution. The surface water quality in a region is largely determined both by the natural processes (precipitation rate, weathering processes, soil erosion) and the anthropogenic influences viz. urban, industrial and agricultural activities and increasing exploitation of water resources [1,2]. The municipal and industrial wastewater discharge constitutes the constant polluting source, whereas, the

* Corresponding author. Tel.: +91 522 2508916; fax: +91 522 2628227.
E-mail address: kpsingh_52@yahoo.com (K.P. Singh).

0003-2670/$ – see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.aca.2005.02.006

surface run-off is a seasonal phenomenon, largely affected by climate in the basin. Seasonal variations in precipitation, surface run-off, ground water flow and water interception and abstraction have a strong effect on river discharge and subsequently on the concentration of pollutants in river water [3]. Since, rivers constitute the main inland water resources for domestic, industrial and irrigation purposes, it is imperative to prevent and control the rivers pollution and to have reliable information on the quality of water for effective management. In view of the spatial and temporal variations in the hydrochemistry of rivers, regular monitoring programs are required for reliable estimates of the water quality. This results in a huge and complex data matrix comprised of a large number of physico-chemical parameters, which are often difficult to interpret and draw meaningful conclusions [4]. Further, for effective pollution control and water resource management, it is required to identify the pollution sources and their quantitative contributions.

The Gomti river, a major tributary of the Ganga river system in India, originates from a natural reservoir in the forested area (elevation of about 200 m; North latitude 28°34′ and East longitude 80°07′) in Uttar Pradesh. The river traverses a total distance of about 730 km before finally merging with the Ganga river near Varanasi. It drains a catchments area of about 25,800 km^2. Kathna, Sarayan, Reth, Luni, Kalyani and Sai rivers are the tributaries of the Gomti river. Lucknow (population about 3.5 million), Sultanpur (population about 0.2 million) and Jaunpur (population about 0.2 million) are

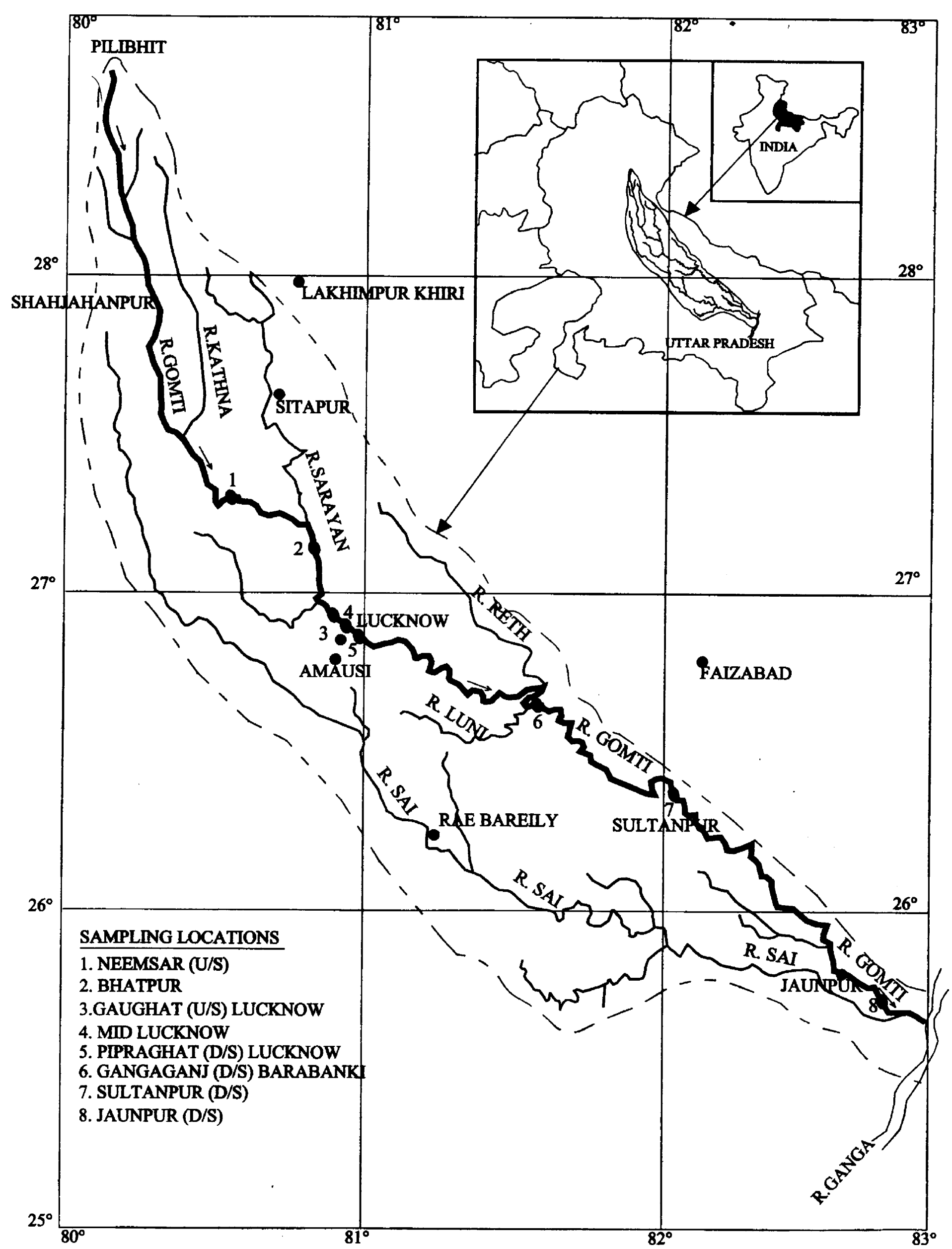

Fig. 1. Map showing the water quality monitoring sites on the Gomti river.